Collecting and using building-specific information to reduce severity of a chemical or biological attack

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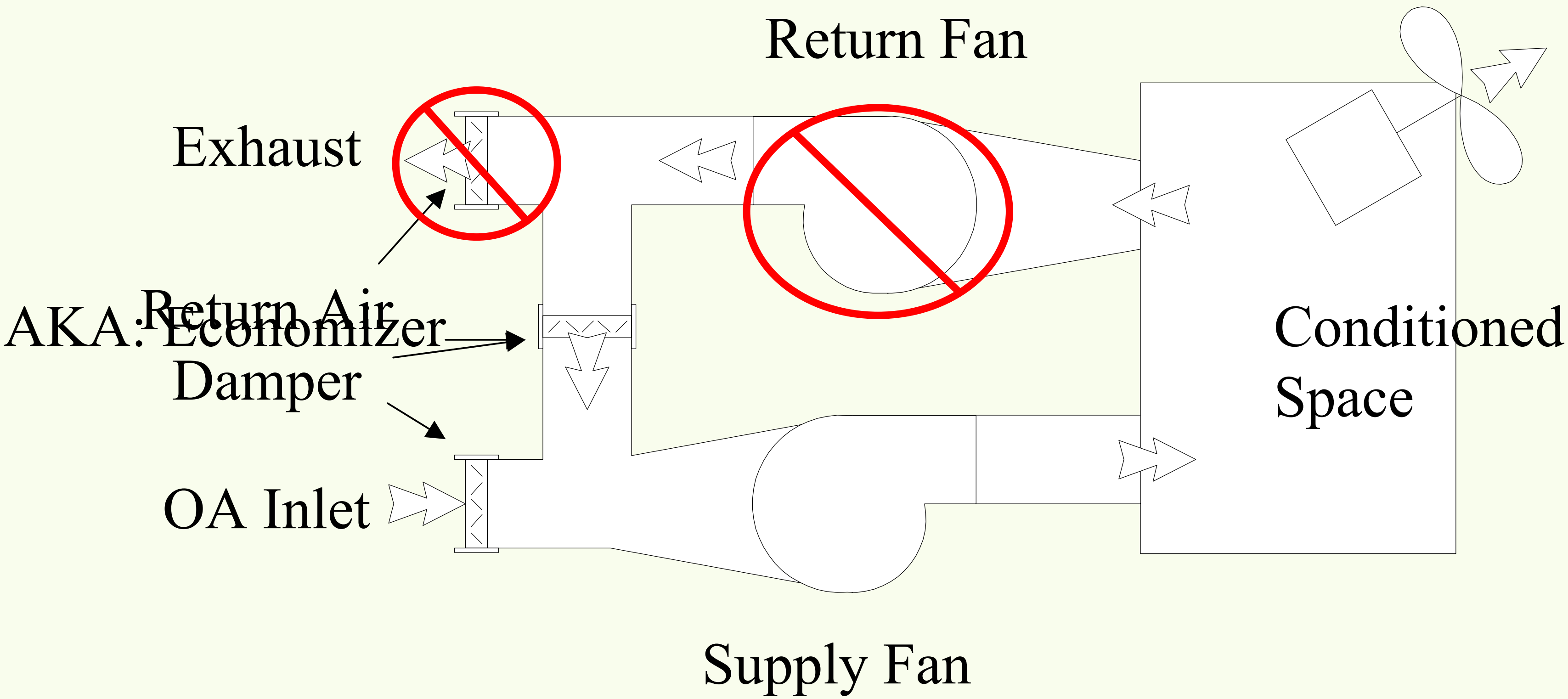
A Typical HVAC System



Understanding your building's behavior!

- Any contingency plan requires a knowledge of how the building actually operates
  - This means normal as well as emergency operations
- This requires careful study of the building
  - Understanding all aspects of the HVAC system(s) layout
  - How the control system operates
- Actual testing may include any and/or all of the following
  - Conventional TAB reports and Retro-commissioning
  - Pressurization tests
  - Tracer gas tests

What is Retro-commissioning?

"..Retro-commissioning ensures system functionality. It is an inclusive and systematic process intended not only to optimize how equipment and systems operate, but also to optimize how the systems function together."

TAB—*Testing Adjusting Balancing* Part of the process


VAV BOX DATA

TESTING AND BALANCING REPORT

Unit Identification

TAG	VAV-1		VAV-2		VAV-2	
LOCATION	CEILING SPACE		CEILING SPACE		CEILING SPACE	
SERVICE	SUITE 640		SUITE 640		SUITE 640	
MAKE/MODEL	MARK HOT		MARK HOT		MARK HOT	
CONTROL SYSTEM IDENTIFICATION	N/AP		N/AP		N/AP	
Operating Data:	SPECIFIED	ACTUAL	SPECIFIED	ACTUAL	SPECIFIED	ACTUAL
MAX FLOW (CFM)	840 (*2)	860 (*2)	705 (*2)	700 (*2)	600 (*2)	620 (*2)
MIN FLOW (CFM)	420	400	350	335	300	280
AREA FACTOR		12"		10"		12"
MAX/MIN ADJ FACTORS		N/AP		N/AP		N/AP

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MAX/MIN ADJ FACTORS						

- Non trivial process
  - 0.20-1.0+ $/ft^2
- Other benefits
  - Reduced energy use (simple payback often <1yr)
  - IAQ improvements
  - Reduced maintenance costs

Pressurization tests

The tests range from simple ΔP measurements across doors to whole building tests

Easy

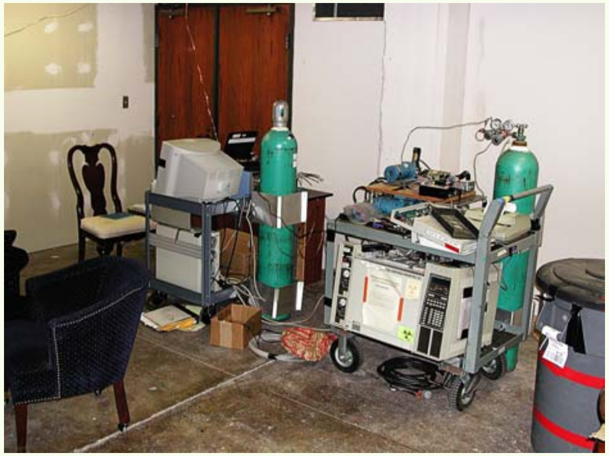
HARD!

The information gained includes likely flow barriers to leakage rate data

Tracer gas tests

Release small amounts of harmless chemicals (tracers) in various parts of the building/HVAC system

Use instruments to quantify how much of the tracer is in the air



The results tell us something about the airflows within the building during the test conditions

We need some form of a model

- Testing alone usually does not answer all possible questions
  - Different seasons, operating conditions, etc…

Possible Models

- Simple pressurization
- Zonal models
  - COMIS, CONTAM
- Computational Fluid Dynamics

Easiest

Hardest

We are really after a fundamental understanding of the mechanisms!

Fundamental Airflow Drivers

- Mechanical Systems
  - Supplies air to spaces for thermal comfort
  - Returns remove air back to the AHUs
  - Exhaust systems
- Thermal Buoyancy
  - Temperature differences between inside and outside can create a big pressure difference in a tall building—Stack Effect
  - Same thing on a smaller scale across doors or large passages—Two way flows
- Wind

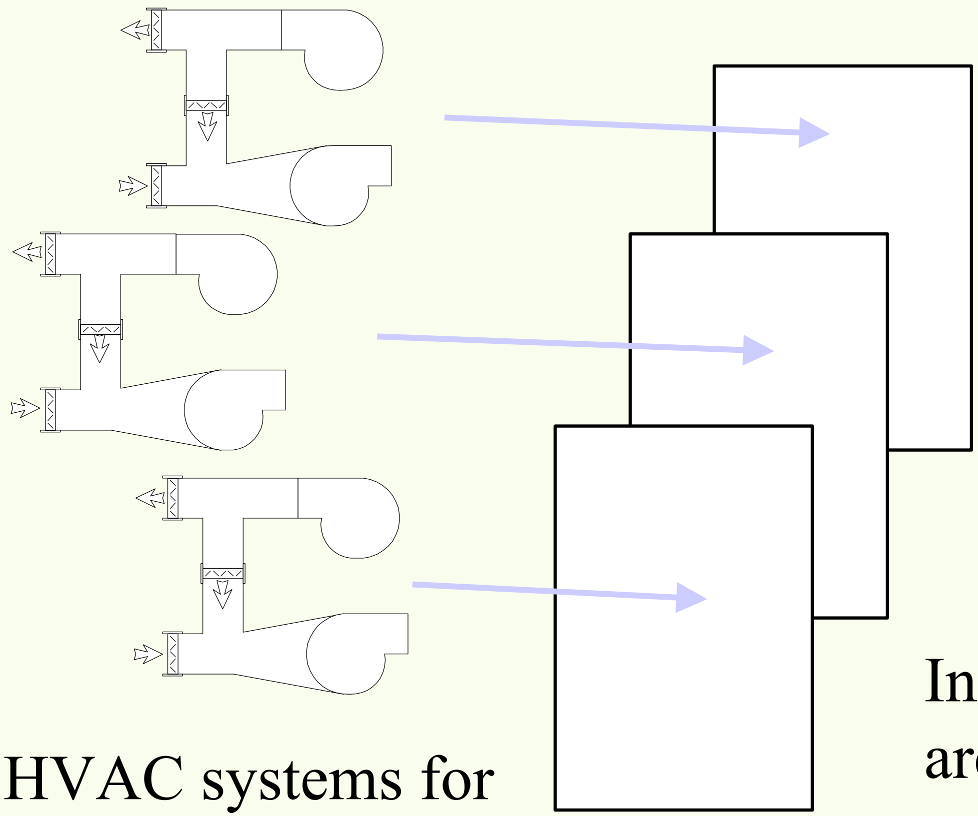
Relative Balance is the key

Changes with the seasons

Temperatures inside are never uniform

Constantly changes, more important for a building that is shut down

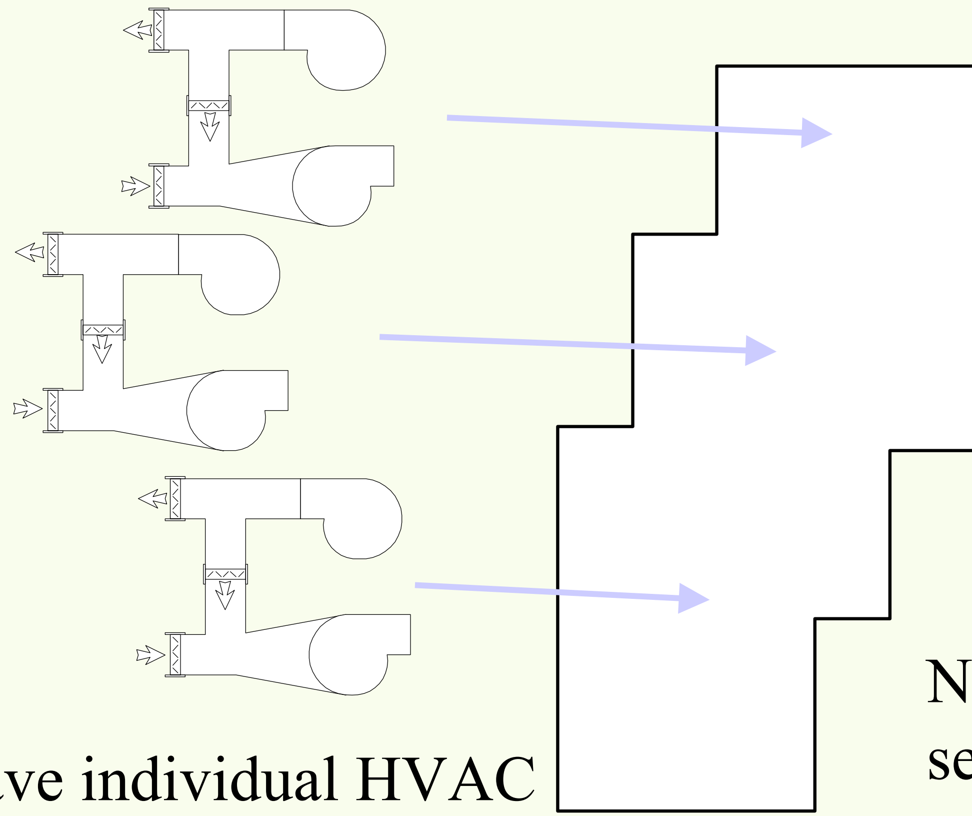
HVAC Zoning



Individual HVAC systems for specific sections of the building

In this case sections are distinct and separated

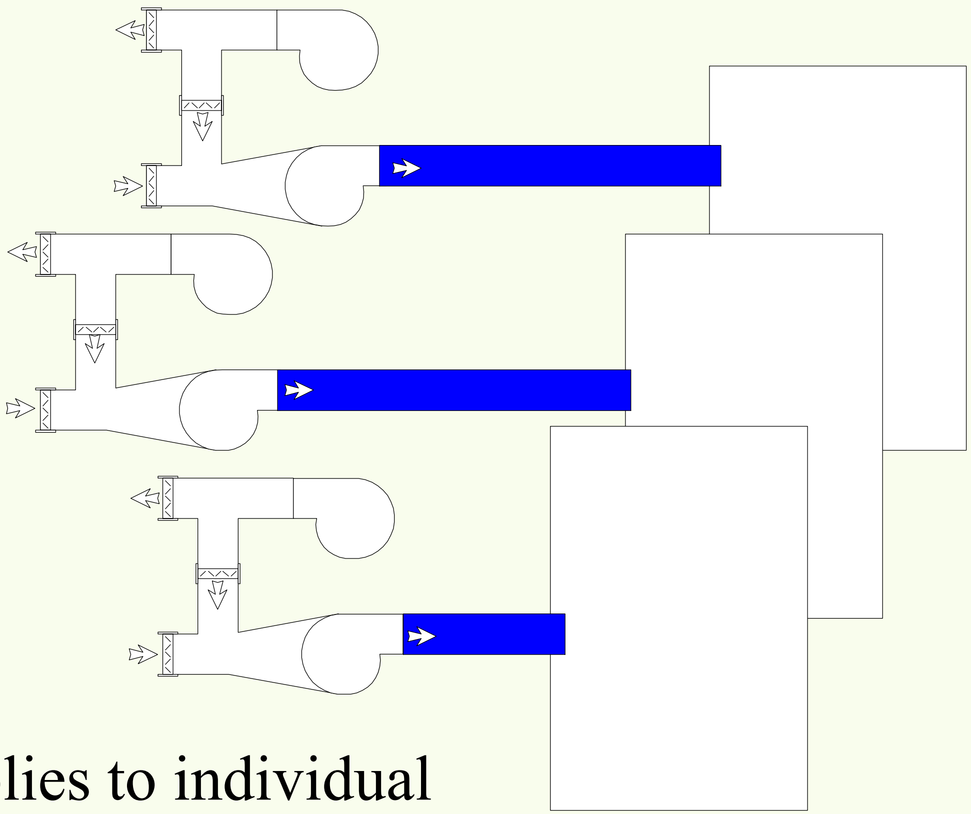
More HVAC Zoning



We still have individual HVAC systems for specific sections of the building

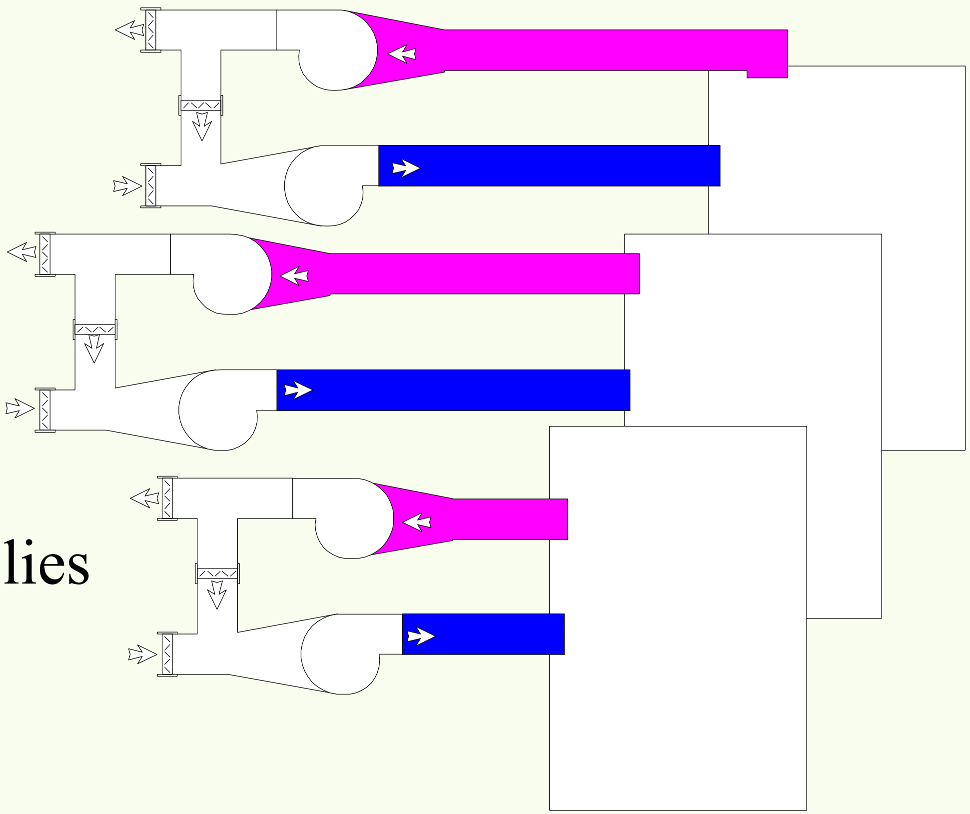
Now the individual sections are not separated

HVAC Supply air path



Distinct supplies to individual sections

HVAC Return air path

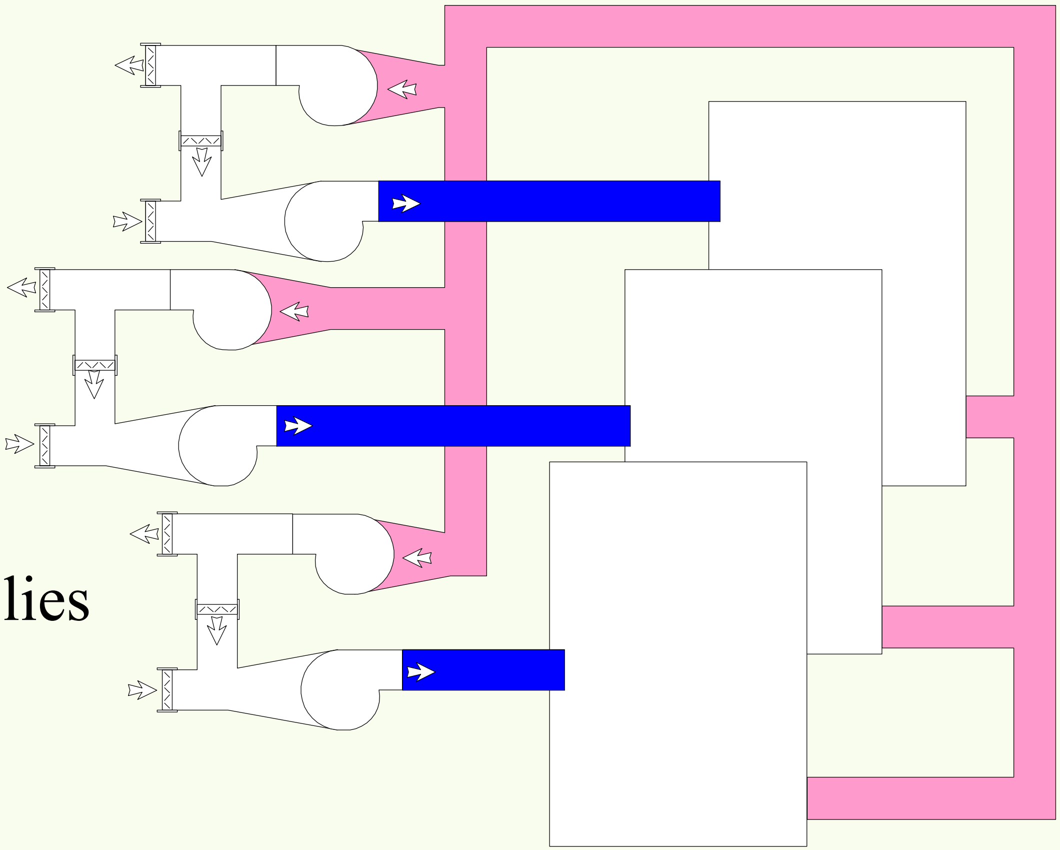


Distinct supplies to individual sections

Distinct returns from individual sections

Reasonable chance of relative containment

Another HVAC Return air path



Returns are mixed

Distinct supplies to individual sections

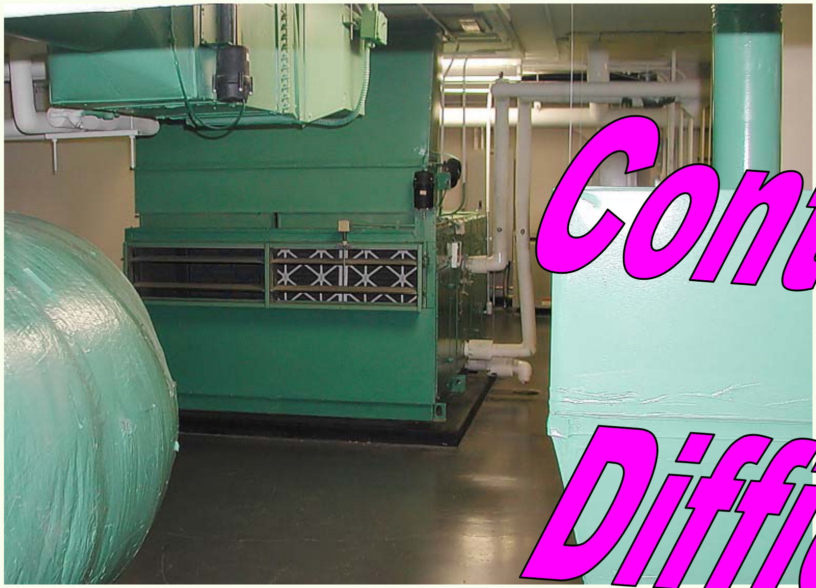
Containment difficult if not impossible

Old building circa ~1910

Old building circa ~1910

Common Returns

Containment Difficult



Systems are shoe-horned into the building

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- This requires careful study of the building
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- Any testing needs to be backed up my some level of modeling

Misc. Material

What's Behind the Drop Ceiling

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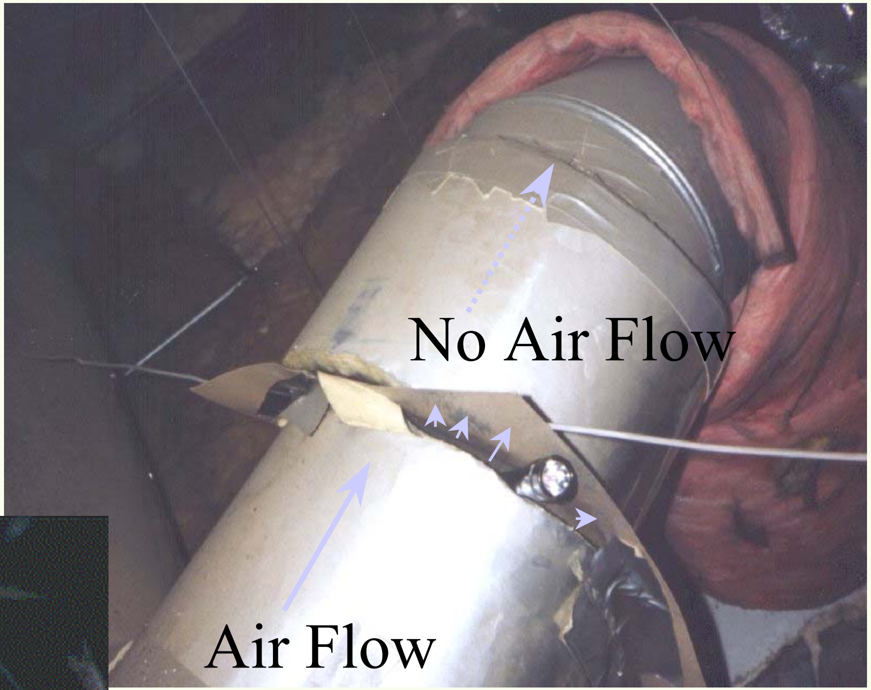
Two Disconnects

←16” Leaking ~400cfm

Abandoned in place
(not leaking) →

"Problems"

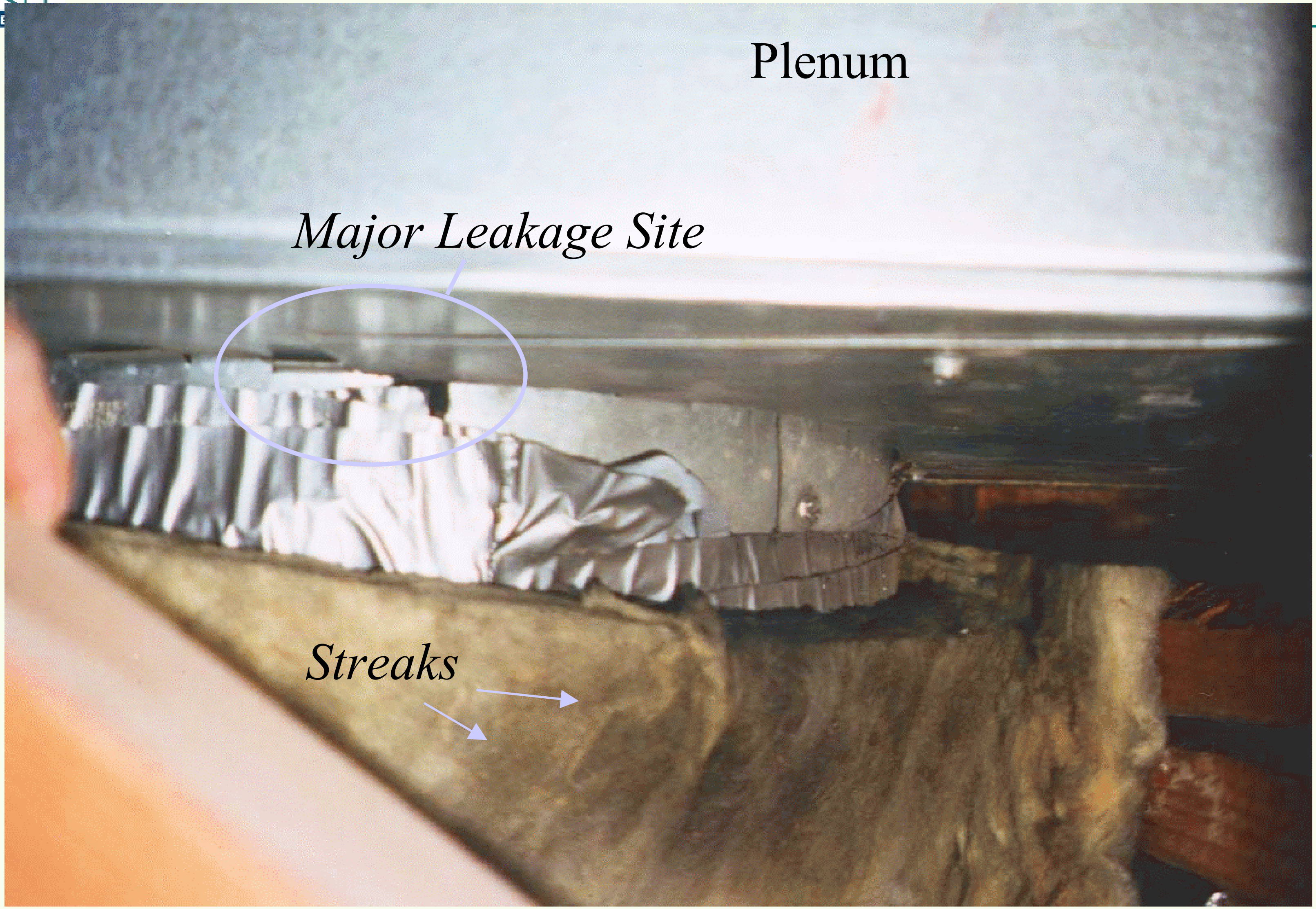
No Flow at the register



150+ cfm at register

Curb and Cabinet Leaks

Major Leak at a fitting



ASHRAE 30-35% Filters????

Obvious Problem

- Failed Filters

Root Causes

- Wet Filters??
- Poor Frame/Filter Fitting!!!!

Sizes

- Nominal 24” x 24”
- Actual $23^{3}/_{8}$ x $23^{3}/_{8}$

BERKELEY LAB

CONTAM 2.1 *

Multizone Airflow and Contaminant Transport Analysis Software

- Nodal (zonal) network model
- Nodes (zones) rooms, etc…
- Network defines the connections
- Each connection has the form

$$\dot{m} = f(\Delta P)$$

- At each node

$$\sum_i \dot{m}_i = 0$$

- Steady State solution for flows
- Transient solution for pollutants – standard mass balance on each node using flows from the SS solution
- The key assumption is each node (zone) is instantaneously well mixed

*http://www.bfrl.nist.gov/IAQanalysis/CONTAMWdesc.htm

CONTAM 2.1 *

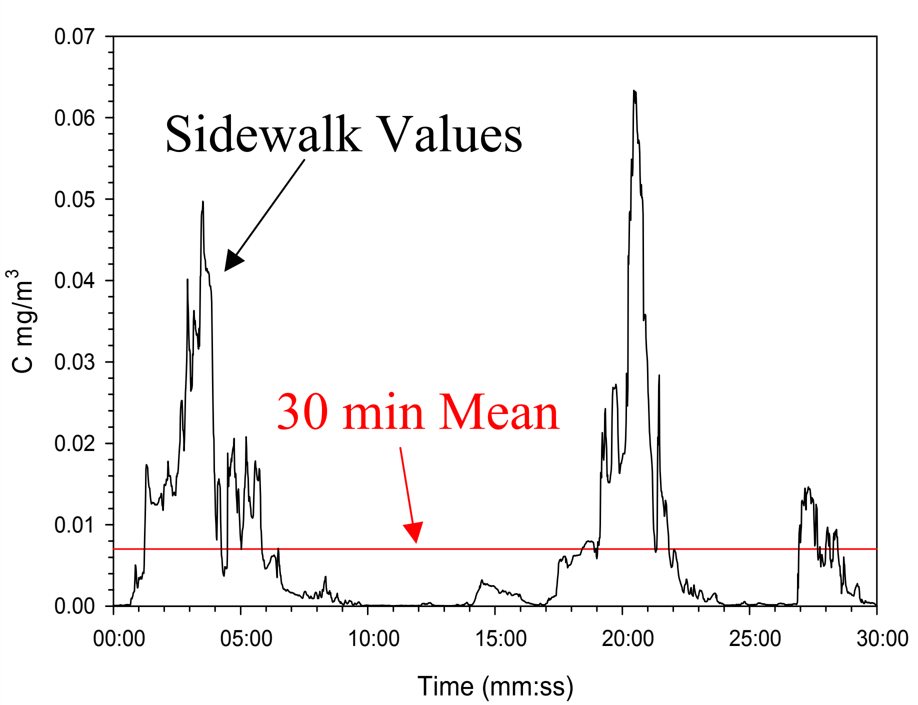
Multizone Airflow and Contaminant Transport Analysis Software

- For most mechanically ventilated spaces (office buildings, etc…) “well mixed” is a good assumption.
  - This is particularly true as you move away form the release, or use the HVAC system for the release.

- We are **pushing the envelope** with the “well mixed” assumption applied to **large grand spaces**!

*http://www.bfrl.nist.gov/IAQanalysis/CONTAMWdesc.htm

Typical OKC Profile



Toxic Load = L(t)

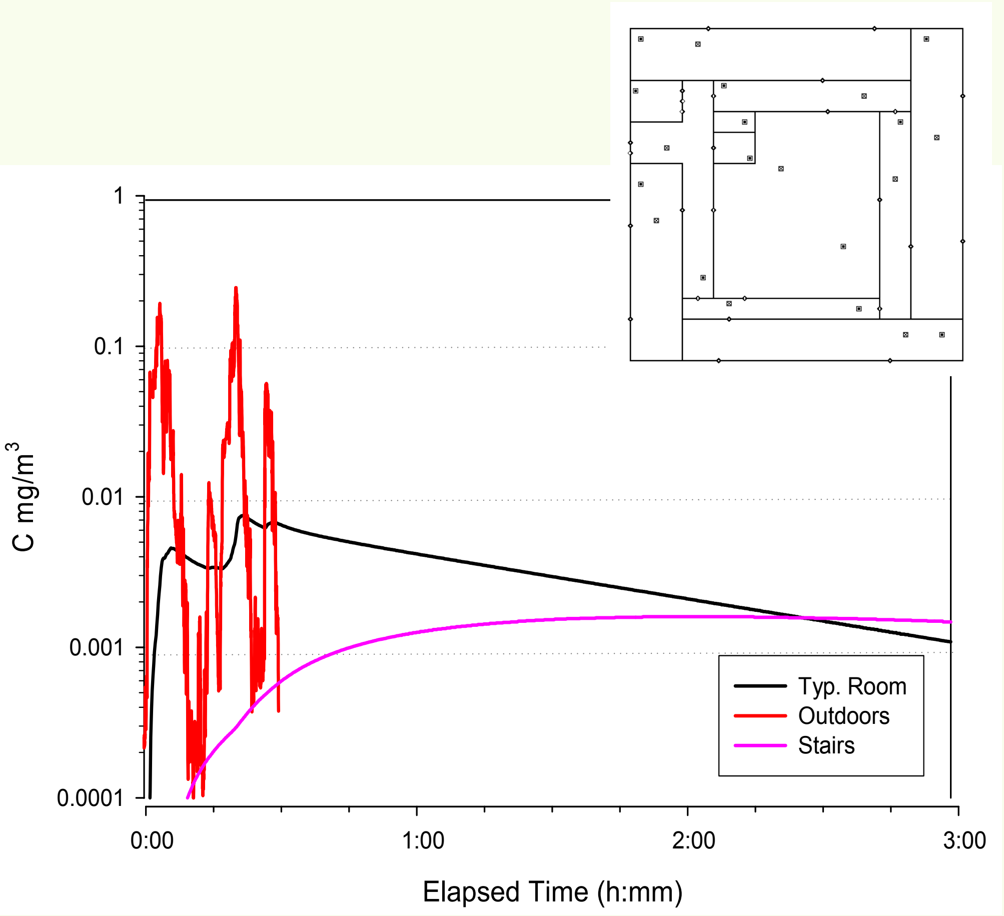
$$L(t) = \int_0^t C(x)^n \, dx$$

For GB n=2

$$\left. \frac{L}{\bar{L}} \right|_{t=30\,\mathrm{min}} = 3.5$$

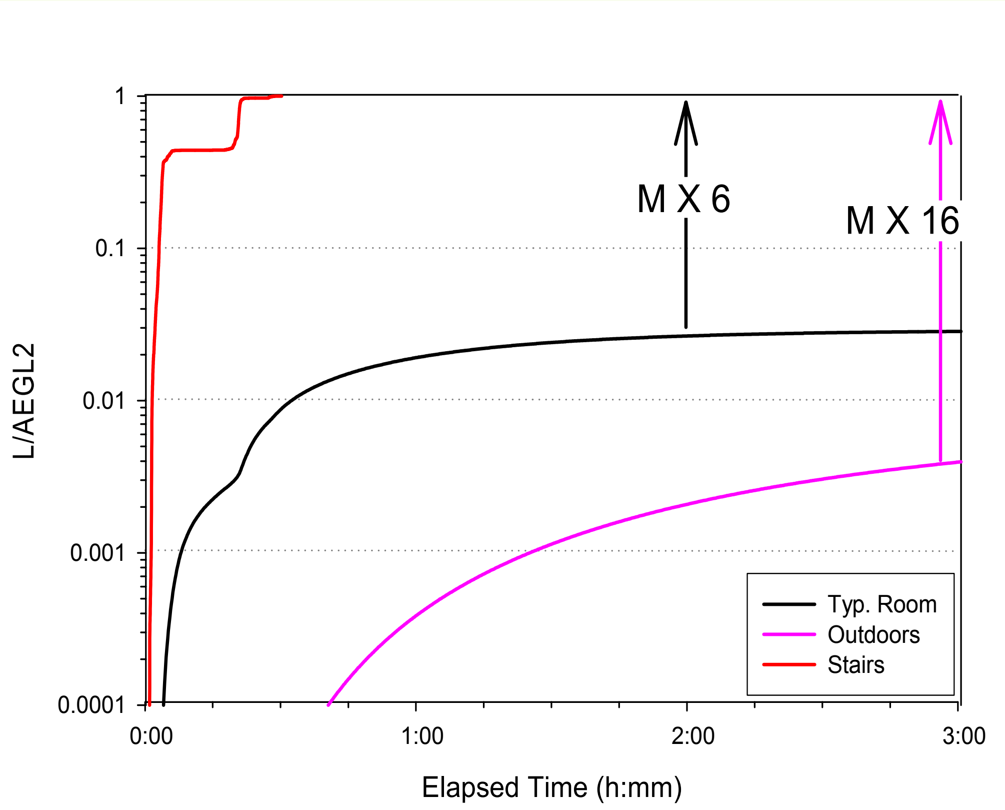
- The peaks due to the turbulent nature of the flow are very dangerous!

Generic Modeling



- CONTAM Model
  - 4 story generic bldg (HVAC left on)
- Scaled the previous outdoor profile
- In the main areas at least an order of magnitude peak reduction
- In the stairs another order of magnitude reduction

Toxic Load/AEGL2



- For a 21kg or 19L release of GB @ ½km

$$MassScalar = \left(\frac{AEGL}{L}\right)^{\frac{1}{n}}$$

$$C \propto \left(\frac{1}{D^2}\right)$$

- Move out to a km and multiply these values by 4

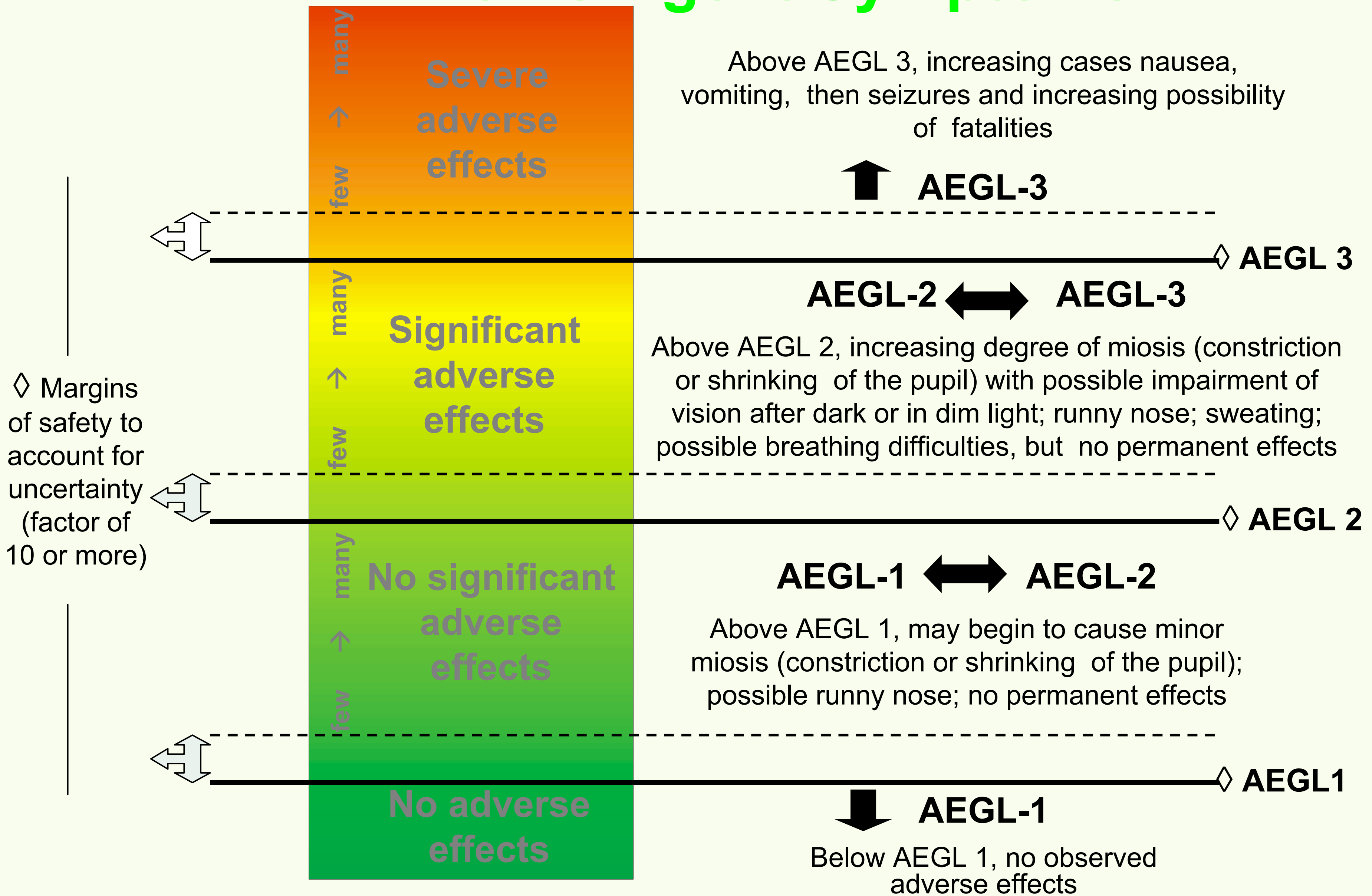
- Even with the HVAC on we have a significant potential for Sheltering in Place!

Modeling Needs

- Conventional wisdom holds that shutting the HVAC units off will enhance Sheltering-in-Place
  - This should change OA of building
- Even with the units off drivers for flow still exist
  - Wind, thermal (stack effects), and smaller units left on

- Characterization data is sorely lacking
  - ~100 data points for large building characteristics as opposed to 10's of K residential buildings
- Large Space limitations with COMIS/CONTAM are even more important
- Stairway model

Nerve Agent Symptoms



◊ Margin of safety addresses uncertainties that may not be completely explained by available data